Fire Effects on Four Growth Stages of Smooth Brome (*Bromus inermis* Leyss.)[1]

Gary D. Willson[2]
USDI Geological Survey
Biological Resources Division
Northern Prairie Wildlife Research Center
Missouri Field Station
University of Missouri-Columbia
Columbia, Missouri 65211 USA

James Stubbendieck
Department of Agronomy
University of Nebraska
Lincoln, Nebraska 68583 USA

ABSTRACT: The invasion and persistence of smooth brome (*Bromus inermis* Leyss.) are serious problems facing managers of warm-season pastures and prairie remnants in the Midwest. Although difficult to control, smooth brome can be reduced when tiller growing points are removed by management activities such as prescribed fire. This study, conducted from 1988 through 1991 at Mead, Nebraska, measured changes in smooth brome tiller density and biomass in seeded, mixed-grass stands following spring prescription burns. Burning was timed to coincide with four smooth brome growth stages and included repeated burns in consecutive years. Burning at tiller emergence did not affect smooth brome tiller density or biomass in years when precipitation was normal or below normal. However, with above normal precipitation, smooth brome biomass more than doubled the year after a tiller-emergence burn. Burning during tiller elongation, heading, and flowering significantly reduced smooth brome tiller density and biomass. Repeated burns, at tiller elongation and later stages, maintained low smooth brome tiller density and biomass. A single burn, however, allowed partial to full recovery of smooth brome density and biomass by the following year. Implications of the study are presented for management consideration.

Index terms: exotic grasses, prescribed fire, smooth brome, tiller development

INTRODUCTION

The invasion and persistence of exotic cool-season grasses, particularly smooth brome (*Bromus inermis* Leyss.), are problems facing managers of warm-season pastures and prairie remnants in the Midwest. In these areas, smooth brome is a highly competitive weed because of its rhizomatous, sod-forming root system and prolific seed production. Smooth brome alters the species composition and production of prairie communities, particularly where past disturbance by domestic livestock grazing or regular mowing has occurred, and it is difficult to control (Boehner 1986, Blankespoor 1987, Becker 1989).

Most studies of smooth brome have focused on its maintenance as a desirable forage grass in seeded pasture. Several of these studies indicated clipping smooth brome during active growth lessens herbage production. For example, Teel (1956), Reynolds and Smith (1962), and Eastin et al. (1964) demonstrated that smooth brome was most easily damaged by grazing or cutting after tiller elongation began in the spring. These results are explained by reduced secondary tillering in smooth brome following growing point removal. Under these conditions, regrowth can only take place by the initiation of new tillers from basal buds, which is inhibited by poorly developed basal buds and low root carbohydrate levels (Paulsen and Smith 1968).

Prescribed fire has been used to control or reduce smooth brome in native prairie with some success. Generally, single burns conducted in late April and in May, presumably at tiller elongation or after, have been effective in reducing smooth brome (Old 1969, Blankespoor 1987, Blankespoor and Larson 1994), whereas single burns conducted earlier have not (Garrett 1992). However, no study has reported the effects of fire on smooth brome as it matures through a spring growing season. This study quantified changes in smooth brome tiller density and biomass following single and repeated prescription burns at four distinct growth stages.

METHODS

Study Site

The study was conducted at the University of Nebraska, Agricultural Research and Development Center, near Mead, Nebraska (41° 10'N, 96° 25'W; 344 m above sea level). The study area at Mead was an 8-ha field planted in 1971 to big bluestem (*Andropogon gerardii* Vitman), little bluestem (*Schizachyrium scoparium* [Michx.] Nash),

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2 At the time of the research, the senior author was a graduate student at the Department of Agronomy, University of Nebraska, Lincoln.

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sideoats grama (*Bouteloua curtipendula* [Michx.] Torr.), Indiangrass (*Sorghastrum nutans* [L.] Nash), and switchgrass (*Panicum virgatum* L.). In 1981, the study site was divided into forty-two 30 x 30-m study areas as part of a long-term investigation of seasonal fire effects (T. Bragg, professor of biology, University of Nebraska, Omaha, pers. com.). Two areas (#13 and #30) were not used in the long-term study and, except for occasional mechanical removal of woody species, were neither burned nor mowed for the 7 years prior to this study. Smooth brome invaded these two areas and became a codominant with big bluestem. During the 3-year study period, precipitation measured at the Mead Agronomy Laboratory 6 km from the study site, varied considerably. Late winter and spring precipitation was near normal in 1990, 47% below normal in 1989, and 35% above normal in 1991 (National Oceanic and Atmospheric Administration 1989, 1990, 1991).

Table 1. Smooth brome morphological growth stages and burn dates for 1989–91 at Mead, Nebraska.

	Burn Dates		
Morphological Growth Stage	**1989**	**1990**	**1991**
Emergence	25 March	03 April	02 April
Elongation	13 May	14 May	10 May
Heading	31 May	04 June	03 June
Flowering	—	18 June	14 June

Sampling Methods

In October 1988, study area #30 was divided into sixteen 6 x 6-m plots, each surrounded by a 1.25-m mowed lane. Fall density and biomass of smooth brome tillers were determined for each plot by counting and hand-clipping at the soil surface all current-year tillers within ten 0.1-m^2 randomly placed quadrats. Biomass samples were dried at 55°C until they reached a constant weight. In spring 1989, one of four treatments was applied to each plot in a completely randomized design with four replications per treatment. Treatments included burning plots at smooth brome tiller emergence, at elongation, and at heading, and no burning. The three growth stages were essentially the same as the VI (first leaf collared), EI (first node palpable/visible), and RI (inflorescence emergence/first spikelet visible) growth stages of perennial forage grasses described and quantified by Moore et al. (1991). In fall 1989, smooth brome density and biomass were determined by randomly resampling the plots using ten 0.1-m^2 quadrats.

Burn dates were timed according to the morphological stage of growth of smooth brome and did not vary by more than 10 days over the 3-year period of study (Table 1). After 50% of randomly sampled tillers within the plots had reached a particular morphological stage, burns were conducted as soon as conditions met the following prescription criteria: temperature between 10°C and 27°C, wind from any direction between 16 and 32 km h^{-1}, and relative humidity between 30% and 70%. Generally, there was only a 2- to 3-day delay between detection of a morphological stage and application of the burn treatment. A back fire was used to burn each plot.

In fall 1989, study area #13 was divided into sixteen 6 x 6-m plots, and density and biomass of smooth brome tillers were determined as in 1988. The experiment was repeated in spring 1990 with the addition of a fourth burn treatment at smooth brome flowering (the R4 [anther emergence/anthesis] growth stage [Moore et al. 1991]). Treatments were applied to each 6 x 6-m plot in a completely randomized design with three replications per treatment. Also, in spring 1990, each of the 16 plots in study area #30 was divided in half along a north/south axis. Either the west or the east half randomly received the same treatment that had been applied in 1989, and the other half received no burn treatment. This provided data for repeated burn treatments (burn/burn) as well as recovery from a single burn (burn/unburned). In spring 1991, the 16 plots in study area #13 were divided in half, as had been those plots in study area #30 in 1990. Half of each plot was then reburned, while the other half was not burned. This provided a second year of data for plots burned once in 2 years and twice in 2 years.

Data Analysis

An analysis of covariance with a means comparison test (F-protected LSD) was used to test for differences in smooth brome tiller density and biomass among treatments within years ($\alpha = 0.05$) (Montgomery 1984). Fall 1988 and 1989 smooth brome tiller density and biomass were the covariates. An analysis of variance with an F-protected LSD test was used to determine smooth brome tiller density and biomass differences by treatment among years ($\alpha = 0.05$). Analyses were performed using SOLO statistical software (BMDP Statistical Software 1991).

RESULTS AND DISCUSSION

Tiller-Emergence Burns

Single burns of smooth brome at the tiller emergence stage in 1989 and 1990 did not change tiller density or biomass as compared to the unburned controls (Figure 1). Results of this study agree with those of Garrett (1992), who found that single, late winter (February) burns in Kansas just before smooth brome tiller emergence had no effect on herbage yield when compared to no burning. In addition, these results are similar to those of Probasco and Bjugstad (1977), who determined that burning tall fescue (*Festuca arundinacea* Schreb.), another cool-season perennial grass, just before active growth in late February did not significantly affect herbage yield compared to no burning.

Other studies (Becker 1989, Rosburg and Glenn-Lewin 1992) noted that a reduction in litter by burning in March and April increased the cover of quackgrass (*Agro-*

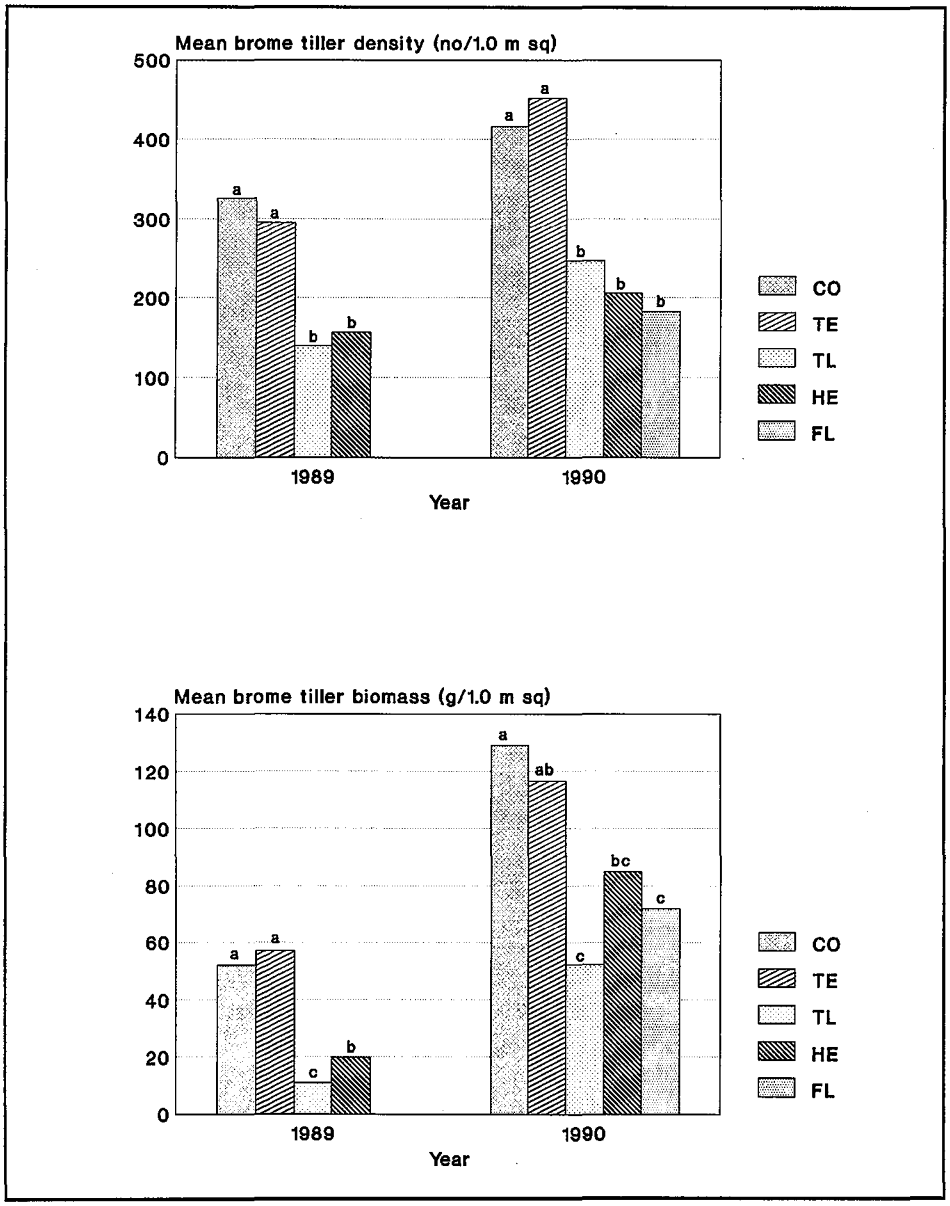

Figure 1. Mean smooth brome tiller density (number m^{-2}) and biomass (g m^{-2}) in the fall following single burns at different growth stages (CO = unburned control, TE = tiller emergence, TL = tiller elongation, HE = tiller heading, and FL = tiller flowering) in 1989 (area #30) and 1990 (area #13) at Mead, Nebraska. Means are adjusted by the 1988 or 1989 pretreatment covariates. Means with the same letter within years are not significantly different (*P*>0.05, LSD).

pyron repens Beauv.) and biomass of tall fescue and Canada bluegrass (*Poa compressa* L.). Furthermore, prairie managers (R. Baynes, superintendent, Homestead National Monument of America, pers. com.; V. Halvorson, superintendent, Pipestone National Monument, pers. com.) have observed more vigorous growth of smooth brome following late March and early April removal of heavy litter. Although litter reduction was not measured in this study, visual inspection of the burned plots indicated that most of the litter was consumed by the fire. Lack of an increase in smooth brome tiller density and/or biomass may be due to lower than normal precipitation in the first 6 months of 1989, with March and April precipitation being particularly low (15 mm and 25 mm, respectively). Similarly, although the first 6 months precipitation in 1990 was near the 30-year average, only 85 mm of precipitation were recorded for April. In this study, burning smooth brome at tiller emergence (late March/early April) may have further reduced soil moisture. This assumption is supported by Anderson (1965), who found differences in soil moisture due to time of burning: early spring (March 20) burned areas were significantly drier than unburned areas. In central Wisconsin, the association between soil moisture and plant response was investigated by Zedler and Loucks (1969), who observed that soil moisture differences between depressions and ridges in a sandy prairie resulted in differences in postfire biomass production of Kentucky bluegrass (*Poa pratensis* L.) and little bluestem. These results suggest that, in a dry spring, the negative effects of reduced soil moisture may counterbalance the positive effects of litter reduction on smooth brome tiller development.

Tiller-Elongation Burns

Single burns of smooth brome at tiller elongation significantly reduced tiller density and biomass in the fall of 1989 and 1990 (Figure 1). These responses may have been due to removal of the apical meristem and loss of secondary tiller biomass similar to that reported in clipping and grazing studies (Teel 1956, Eastin et al. 1964, Paulsen and Smith 1969, Krause and Moser 1977). Burning smooth brome at tiller elongation may have reduced secondary tillering because of low carbohydrate reserves, low basal bud activity, and differential levels of growth regulating hormones at the time of tiller removal (Winch et al. 1970, Kunelius et al. 1974). Furthermore, smooth brome and other cool-season grasses burned at this time endure not only physiological stress from forced regrowth but also competitive stress in mixed stands from enhanced growth of warm-season grasses (Rosburg and Glenn-Lewin 1992, Blankespoor and Larson 1994). In a companion study at Mead, big bluestem flower culm density significantly increased following the burn at the smooth brome tiller elongation stage in 1989 and 1990 (Willson 1994). These results are consistent with other studies of big bluestem, which show that the greatest enhancement in flowering occurs after late spring fire (Henderson et al. 1983, Benning and Bragg 1993). In big bluestem, flowering response is associated with in-

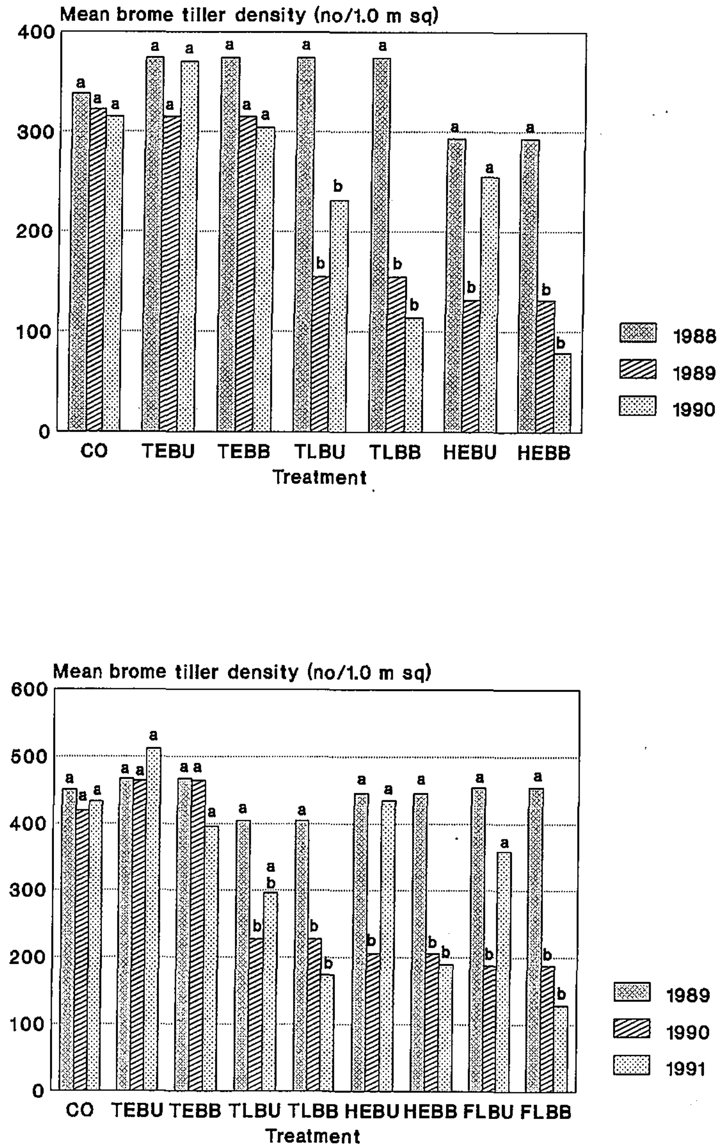

Figure 2. Mean smooth brome tiller density (number m^{-2}) prior to burning (fall 1988 and 1989) and following single and repeated burns at different growth stages (CO = unburned control, TEBU = tiller emergence burn/unburned, TEBB = tiller emergence burn/burn, TLBU = tiller elongation burn/unburned, TLBB = tiller elongation burn/burn, HEBU = tiller heading burn/unburned, HEBB = tiller heading burn/burn, FLBU = tiller flowering burn/unburned, and FLBB = tiller flowering burn/burn) in areas #30 and #13 at Mead, Nebraska. Means with the same letter within treatments are not significantly different (*P*>0.05, LSD).

creased biomass production and may be an indicator of competitive vigor (Henderson et al. 1983).

Tiller-Heading and Tiller-Flowering Burns

Single burns of smooth brome at more developed growth stages negatively affected both tiller density and biomass. In 1989 and 1990, a burn treatment at tiller heading significantly decreased smooth brome tiller density and biomass compared to control plots. In 1990, burns at tiller flowering also produced significant decreases (Figure 1).

In 1989, burning at tiller heading was less damaging to smooth brome than burning at tiller elongation: biomass following the tiller-elongation burn was signficantly lower than biomass following the tiller-heading burn (Figure 1). Kunelius et al. (1974) found similar results following cutting of smooth brome at eight developmental stages. In their study, dry matter yields from smooth brome regrowth after first cutting were higher at advanced stages of development (heading or later) than at less mature stages (elongation to early heading). The effect of burning smooth brome at the tiller-heading stage on secondary tillering should be less than that at tiller elongation because of higher carbohydrate reserves at heading. Why a similar response was not found in 1990 is not known. Conversely, both tiller-elongation and tiller-flowering burns produced similar reduced secondary tiller responses (Figure 1) because both of these smooth brome growth stages are low in carbohydrates.

Single and Repeated Burns

The 1989–90 and 1990–91 tiller-emergence burn/unburned treatments produced no significant differences in smooth brome tiller density among years (Figure 2). The effect of the 1989–90 tiller-emergence burn/unburned treatment on smooth brome biomass production was similar to that on tiller density, but biomass production more than doubled in 1991 under the 1990–91 burn/unburned treatment (Figure 3). Reduced litter, adequate precipitation, and the absence of burning may have allowed this increase in biomass production that year.

Repeated burns of smooth brome at tiller emergence produced significantly lower biomass in the 1989–90 burn/burn treatment but not in the 1990–91 burn/burn treatment (Figure 3). Although single burns at this morphological stage do not adversely affect smooth brome (Figure 1), repeated burns, even when conducted too early to kill tillers, still may have some negative effect on smooth brome. For example, Becker (1989) found reductions in smooth brome shoot height and flowering and seed production after 5 years of annual burns, conducted before smooth brome tiller elongation, from middle to late April. Similarly, in central Alberta, Anderson and Bailey (1980) found 24 years of annual early

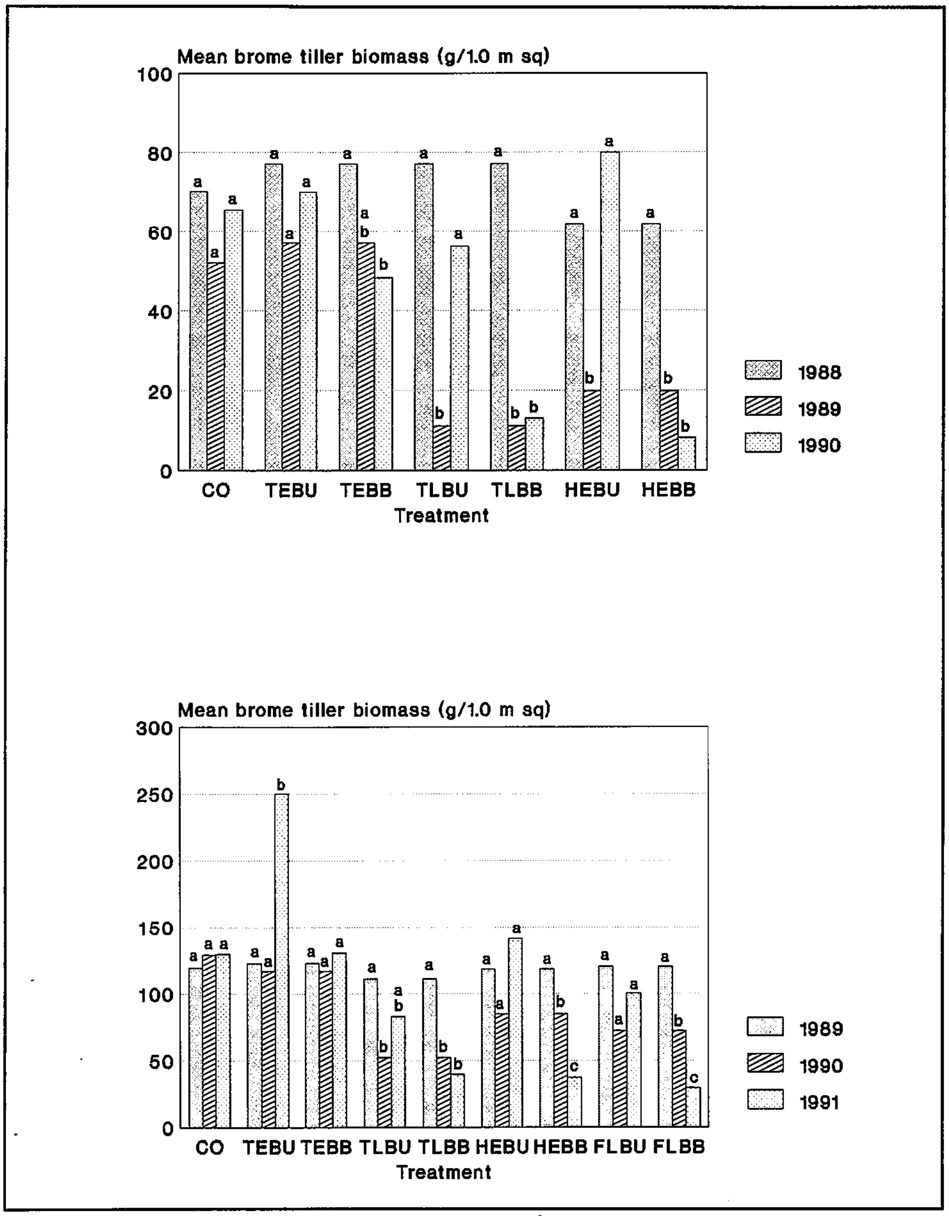

Figure 3. Mean smooth brome tiller biomass (number m^{-2}) prior to burning (fall 1988 and 1989) and following single and repeated burns at different growth stages (CO = unburned control, TEBU = tiller emergence burn/unburned, TEBB = tiller emergence burn/burn, TLBU = tiller elongation burn/unburned, TLBB = tiller elongation burn/burn, HEBU = tiller heading burn/unburned, HEBB = tiller heading burn/burn, FLBU = tiller flowering burn/unburned, and FLBB = tiller flowering burn/burn) in areas #30 and #13 at Mead, Nebraska. Means with the same letter within treatments are not significantly different (*P*>0.05, LSD).

spring (April) burns decreased both frequency and canopy cover of smooth brome. In addition, T. Bragg (pers. com.) found that plots at Mead, Nebraska, that were originally codominated by big bluestem and smooth brome were nearly pure stands of big bluestem after 10 years of annual late-April burns. The reasons for this are not known but may involve a combination of severe defoliation of smooth brome tillers (the tiller is still alive but substantial leaf area is removed) (Henderson et al. 1983) and an enhancement of growing conditions for competing big bluestem (Willson 1994) and other warm-season grasses (Henderson et al 1983).

In the 1989–90 tiller-elongation burn/unburned treatment, smooth brome tiller density and biomass declined and remained below preburn levels, although only tiller density remained significantly lower (Figures 2 and 3). This persistent effect is consistent with the report by Gates et al. (1982), which showed that there was a suppression of smooth brome yield 1 year after an April 29 burn. In addition, Blankespoor (1987) found that cool-season biomass in smooth brome-dominated plots was below the preburn level 1 year after a May 14 burn.

Repeated burns of smooth brome at tiller elongation in the 1989–90 and 1990–91 burn/burn treatments maintained tiller density and biomass significantly below preburn levels (Figures 2 and 3). These results show that in mixed stands with big bluestem, repeated burns of smooth brome at tiller elongation can maintain smooth brome tiller density and biomass below preburn levels.

Except for biomass in 1990–91, the responses following the 1989–90 and 1990–91 tiller heading burn/unburned treatments showed both smooth brome tiller density and biomass significantly declining and returning to preburn levels (Figures 2 and 3). In the 1990–91 burn/unburned treatment, tiller biomass did not change from preburn levels (Figure 3). These results may reflect seasonal trends in smooth brome carbohydrate reserves, which increase during tiller elongation until heading (Teel 1956). They also may reflect seasonal differences in precipitation and litter reduction following burn treatments. In May 1990, high carbohydrate reserves at heading, reduced litter, and adequate moisture may have enhanced secondary tiller growth of smooth brome, thus mitigating year-of-burn tiller losses. Furthermore, high carbohydrate reserves at heading may enhance tillering and tiller growth in the year following a burn. These results are in contrast to repeated burns at tiller heading, which produced 2 years of reduced smooth brome tiller density and biomass that differed significantly from preburn levels (Figures 2 and 3).

The significant decline and recovery of smooth brome tiller density following the tiller flowering burn/unburned treatment (Figure 2) were similar to the response following the tiller elongation burn/unburned treatment, which corresponds to an early season carbohydrate low. This result is, again, consistent with the expected response based on previous studies on carbohydrate reserves in smooth brome. Teel (1956), for example, showed carbohydrates decreased during flowering to a second seasonal low at anthesis. In contrast, the absence of significant changes in tiller biomass following the tiller-flowering burn/unburned treatment closely paralleled the response following the tiller-heading burn/unburned treatment (Figure 3). Near normal precipitation in May and June 1990 and reduced litter after the burn may have promoted robust growth of secondary tillers. Repeated burns at tiller flowering maintained both smooth brome tiller density and biomass at significantly lower levels than occurred before treatment (Figures 2 and 3). This response was similar to that found after the tiller-elongation and tiller-heading burn/burn treatments.

MANAGEMENT IMPLICATIONS

This study was designed to show differences in tiller response to prescribed fire applied at different growth stages of smooth brome when growing in combination with big bluestem. In this situation, burning during the tiller elongation phase was the most effective in reducing smooth brome tiller density and biomass (Figure 1). Managers can determine when smooth brome tillers are elongating by searching for an aboveground node or, alternatively, by counting at least five green leaves per tiller (Willson 1992).

Managers may have an additional smooth brome control option if burning can be repeated. In this study, burns before tiller elongation in March and April resulted in a progressive reduction in smooth brome biomass in 1988–90, although not in 1989–91 (Figure 3). The results in 1988–90 and those of Anderson and Bailey (1980) and Becker (1989) suggest that annual burns generally conducted too early to kill tillers still may have some negative effect on smooth brome. However, managers should be aware that a single burn before tiller elongation could enhance smooth brome through beneficial factors associated with litter reduction, such as light enrichment. In 1991, under above-normal precipitation, biomass production of smooth brome more than doubled the year after a single tiller-emergence burn (Figure 3). In addition, in another study at Mead, Nebraska, Willson and Stubbendieck (1995) found that early spring burning of smooth brome-dominated sites during a dry period led to less soil moisture and lower soil temperatures as compared to early burned big bluestem-dominated sites. In areas where smooth brome and big bluestem are codominant, a burn before tiller elongation could benefit smooth brome by minimizing conditions necessary for early growth of competing big bluestem, such as increased soil temperature (Hulbert 1988).

Managers should delay burning smooth brome to a subsequent year if tillers show an inflorescence (i.e., are heading). Although this study showed significant reductions in tiller density and biomass following burning at heading and at flowering, the reductions for biomass were not as great as those at tiller elongation (Figure 1). Furthermore, this study showed that smooth brome did not recover to preburn levels the year after a burn at the tiller elongation stage but did the year after a burn at the heading stage (Figures 2 and 3).

Gary Willson is an Ecologist at the Missouri Field Station, Biological Resources Division, U.S. Geological Survey, and an Adjunct Assistant Professor in the School of Natural Resources, University of Missouri in Columbia. He administers long-term ecological monitoring programs in national parks of the Ozarks and central Great Plains. He also conducts research on the effects of fire on exotic and rare plants.

James Stubbendieck is Professor of Rangeland Ecology at the University of Nebraska in Lincoln. He teaches senior/graduate-level courses on ecology, taxonomy, and sampling techniques. He conducts research on prescribed burning and the ecology of endangered species.

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